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LETHBRIDGE WIND RESEARCH TEST SITE: EVALUATION OF WIND AND SOLAR PUMPING SYSTEMS, 1991 FINAL REPORT

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EXECUTIVE SUMMARY

The Lethbridge Wind Research Test Site was established in 1982 for the purpose of evaluating and demonstrating the use of water pumping wind turbines for local agricultural applications. The test site has since diversified to include solar pumping systems and deep well systems suitable for export markets.

This report presents the results of the tests performed during the 1991 test season. Complete tests were performed on ten water pumping systems (five solar systems, five wind systems). An additional wind system was on the site during 1991 but was under construction.

This report is the last which will be generated under the Lethbridge Wind Research Test Site banner. During 1991, LWRTS personnel designed and constructed a replacement test site at Pincher Creek, Alberta. The new test site will be known as the Alberta Renewable Energy Test Site (ARETS). An overview of the design and construction of ARETS is provided. The new test site will also be able to provide remote monitoring services as well as provide other industry proponents with short-term resource assessment equipment due to additional funding by Energy, Mines & Resources Canada. A description of the data loggers planned utilization in 1992 is described.

The 1991 test results mark the end of a four year period which will have an Evaluation Report generated by the Alberta Farm Machinery Research Centre. The Evaluation Report will include the Specification and Performance Summary sheets produced on 17 wind pumping systems and 16 solar pumping systems. This report is distributed to over 8000 subscribers who are typically responsible for either the purchase or recommendation for purchase of agricultural equipment.

The test results during 1991 indicate that there are Canadian manufacturers of wind and solar pumping systems with products that are commercially feasible from a technical development point of view. There is also an indication that new manufacturers have the capability of reaching this goal. This combined with the site's increased services (remote monitoring) and exposure (evaluation reports), is expected to spur the growth of Canada's renewable energy water pumping industry.

RÉSUMÉ

Le Terrain d'essais pour recherches éoliennes de Lethbridge (LWRTS) a été établi en 1982 dans le but de faire l'évaluation de turbines éoliennes conçues pour le pompage de l'eau à des fins agricoles et d'en faire la démonstration. Depuis lors, le lieu d'essais s'est diversifié de sorte que l'on y retrouve maintenant des systèmes de pompage à l'énergie solaire et des systèmes de puits artésiens, adaptés aux marchés d'exportation.

Le rapport présente les résultats des essais réalisés pendant la saison 1991. Dix systèmes de pompage ont fait l'objet d'une gamme complète d'essais (cinq systèmes solaires, cinq systèmes éoliens). Il y avait également un autre système éolien sur place en 1991 mais celui-ci était en construction.

Ce rapport sera le dernier compte rendu présenté sous l'enseigne du Terrains d'essais pour recherches éoliennes de Lethbridge. En 1991, le personnel du LWRTS a conçu et construit un nouveau terrain d'essais à Pincher Creek, en Alberta. Le nouveau terrain, qui sera connu sous le nom de l'Alberta Renewable Energy Test Site (ARETS), permettra d'offrir des services de surveillance à distance ainsi que d'évaluation des ressources, grâce à des fonds additionnels d'EMR Canada. Nous avons incorporé une vue d'ensemble de la conception et de la construction d'ARETS ainsi qu'une description de la compilation des données prévues pour 1992.

Les résultats obtenus en 1991 soulignent la fin d'une période de quatre ans pour laquelle l'Alberta Farm Machinery Research Centre produira un rapport d'évaluation. Le rapport comprendra les spécifications et le compte rendu de rendement de 17 systèmes de pompage fonctionnant à l'énergie éolienne et 16 systèmes à l'énergie solaire. Le rapport sera envoyé à plus de 8 000 abonnés choisis parmi des gens qui sont responsables d'acheter et de faire des recommandations pour acheter de l'équipement agricole.

Les résultats d'essais pour 1991 indiquent qu'il existe actuellement des fabricants canadiens de systèmes de pompage aux énergies éolienne et solaire qui offrent des produits rentables du point de vue du développement technique. On peut conclure également qu'il y a de nouveaux fabricants qui ont la capacité d'atteindre ce but. Ces raisons expliquent pourquoi l'industrie du pompage de l'eau à partir d'une forme renouvelable d'énergie est appelée à prendre de l'essor au Canada surtout si elle fait l'objet d'une surveillance accrue des sites (surveillance à distance) et d'un meilleur suivi (rapports d'évaluation).

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LETHBRIDGE WIND RESEARCH TEST SITE
1991 FINAL REPORT

1.0 INTRODUCTION

The Lethbridge Wind Research Test Site was created in 1982 by Alberta Agriculture as a program of testing and demonstrating commercially available wind turbines for agricultural water pumping applications. In 1987, the scope of the project was expanded to include photovoltaic pumping systems to reflect the growing competitiveness that these systems had attained. The three main objectives of the study have remained constant throughout the ten years of operation and are:

1) Evaluate the potential for wind turbines and solar systems to efficiently pump water for agricultural uses.
2) Monitor, demonstrate and evaluate various types of wind and solar pumping equipment developed, manufactured or distributed in Alberta and Canada.
3) Maintain a Canadian focal point for expertise in the design, evaluation and application of wind and solar water pumping systems and related technology.

The Lethbridge Wind Research Test Site is located immediately east of the city of Lethbridge, Alberta, Canada. Presently, it is managed and operated jointly by Alberta Agriculture (Lethbridge), the Lethbridge Community College and DRB Engineering Consultants Ltd. (Calgary, Alberta). Funding for the Test Site has been provided by a number of agencies including: Alberta Heritage Trust Fund, Alberta/Canada Energy Resources Research Fund, Department of Energy, Mines and Resources Canada, Alberta Agriculture, the Farming For the Future Fund and TransAlta Utilities Corporation.

Mr. R. Atkins, Manager of the Alberta Farm Machinery Research Centre of Alberta Agriculture is responsible for overall management of the Test Site. Mr. W. Evdokimoff, Associate Dean of Business & Industry Development at the Lethbridge Community College

is responsible for administering and coordinating the funding contributions and their disbursement. Mr. D. Baker, President of DRB Engineering Consultants Ltd. is responsible for data collection and analysis and computer systems operation and maintenance. He is also responsible for site design and liaison with wind turbine and solar manufacturers. Temporary staff are hired as required to assist with day-to-day operation and maintenance of the site during summer operations.

Numerous publications have resulted from the testing carried out at the Lethbridge Wind Research Test Site since its formation (Atkins et al, 1991, Baker et al, 1989, 1987, 1986; Paterson et al, 1990, 1989, 1988, 1987, 1986). Demonstration days and informal tours are held to educate the public and allow manufacturers to present their machines. The response from these demonstration days and publications has helped to shape the direction and test methods presently found at the Test Site. In 1987, a well simulator was designed and constructed to allow for better evaluation of wind and solar systems at pumping depths up to 250 metres. This will provide needed information for manufacturers wishing to export their machines overseas.

This report describes the results of the testing carried out over the 1991 test season at the Lethbridge Wind Research Test Site. In many cases, manufacturers carried out modifications to their machines during the testing period. The results presented in this report reflect the latest configuration of the machines located at the Test Site. The test results of each machine are presented as "stand-alone" sections of the report such that they may be better utilized by the manufacturers.

This report also describes the construction of the Alberta Renewable Energy Test Site (ARETS) at Pincher Creek, Alberta. This new test site will take over the responsibilities of the Lethbridge Wind Research Test Site as of the 1992 test season. In 1992 the Lethbridge Wind Research Test Site will be dismantled and the land returned to the leasing farmer. However, the Alberta Farm Machinery Research Centre has indicated that it may provide a specialized testing service in Lethbridge. The testing would be designed to assist manufacturers in the process of product development who wish to maintain confidentiality of their design.

2.0 SITE DESCRIPTION

2.1 Site Overview

The Lethbridge Wind Research Test Site is located one kilometre east of Lethbridge and is adjacent to an irrigation canal within the Saint Mary River Irrigation District. The site was selected for the homogeneity of the surrounding terrain and the availability of water for the pumping circuits. Flat agricultural fields that surround the test site cause a minimal amount of interference with the wind flow. The site, because of its location beside the canal, was affected by a high water table and salinity problems due to canal seepage. A subsurface drainage system was therefore designed and installed in order to dewater the area plus provide a practical demonstration of actual field conditions in which the wind and solar pumpers would work.

2.2 Site Layout

Five wind turbines and five photovoltaic water pumping systems were tested during the 1991 test season. A sixth wind turbine was under construction and not yet available for testing. The location of these is shown in Figure 2.1. Tables 2.1 and 2.2 provide summary information on the pumping systems tested. More detailed descriptions are presented with the performance results later in this report.

2.3 Instrumentation and Monitoring Equipment

To measure the pumping performance of the systems, closed-loop double sump systems were installed. A schematic of a typical pumping circuit is shown in Figure 2.2. The unit being tested pumps water from one sump, up a predetermined height and then into a vented standpipe. The piping used in this portion of the test circuit is sized

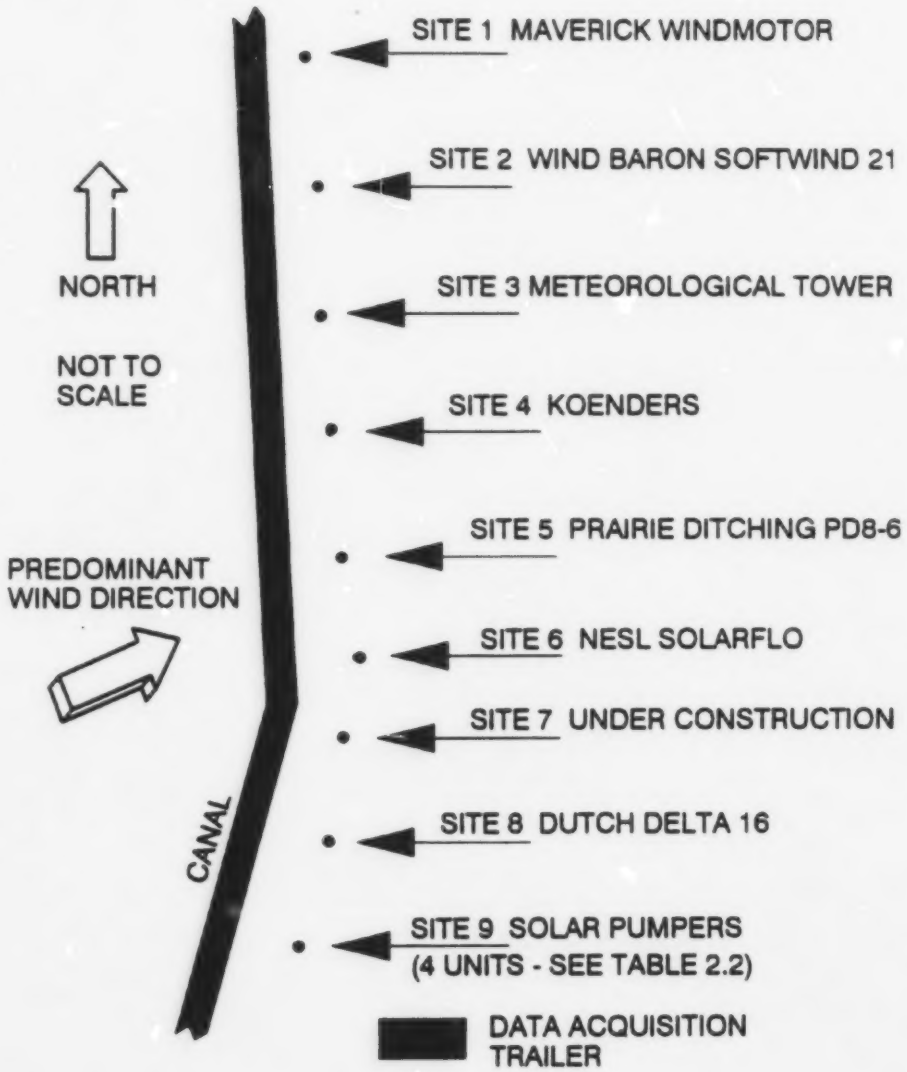


FIGURE 2.1 - LWRTS 1991 TEST SEASON LAYOUT

TABLE 2.1 - WIND PUMPING SYSTEMS TESTED

Model	Description	Supplier
Delta 16	Multiblade rotor, piston pump driven with a counter balance system	Dutch Industries, Regina, Saskatchewan (306) 949-9522
Koenders	12-blade rotor, direct drive air diaphragm operating proprietary pump.	Koenders Mfg. Co. Ltd. Englefield, Saskatchewan (306) 287-3139
Maverick Windmotor	3-blade rotor, cable driven progressing cavity pump	Maverick Wind Energy, Pincher Creek, Alberta (403) 627-3630
Prairie #PD8-6	Multiblade rotor, air lift pump with a direct drive air compressor	Prairie Ditching, Lethbridge, Alberta (403) 327-8280
Softwind 21	Multiblade rotor, piston pump driven with a counter balance system	Wind Baron Corp., Flagstaff, Arizona, USA (602) 526-6400

to be consistent with actual field applications while presenting negligible dynamic head to the pump. The vented standpipe is used to separate air from the pumped water and to dampen the pulsating flows before draining through a flow-metered pipe into the second sump. Each of the turbine-type flow meters is equipped with a flow rate register for local readout as well as a pickup for remote sensing. To ensure valid flow readings, the metered pipe is sloped to maintain submergence of the flow meter and is sized to decrease the turbulence in the pumped water before measurement. The design also ensures that the dynamic head developed in this section will not raise the water level in the standpipe to a point where it would contribute to the pumping head of the wind turbine. The water exiting the metered pipe provides potential users with visual evidence of the wind or solar pumper's capabilities. The loop is completed when the

TABLE 2.2 - SOLAR PUMPING SYSTEMS TESTED

Model	Description	Supplier
CAP 2 Panel	2 tracking ARCO photo-voltaic panels driving a 2 valve diaphragm pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779
CAP 3 Panel	3 fixed ARCO photo-voltaic panels driving a 4 valve diaphragm pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779
CAP 4 Panel	4 tracking ARCO photo-voltaic panels driving a centrifugal pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779
CAP 8 Panel	8 fixed ARCO photovoltaic panels driving a centrifugal pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779
NESL SolarFlo	2 fixed Kyocera photo-voltaic panels driving a 2 valve diaphragm pump	Nor'wester Energy Systems, Calgary, Alberta (403) 249-3337

pumped water returns to the first sump through a connecting pipe located near the base of the two sumps.

Atmospheric monitoring for the wind turbines is performed by a centrally located meteorological tower. A Climatronic weather monitoring package is installed on the 16 metre tower and includes:

1) Four horizontal wind speed sensors mounted at 7.5, 10.0, 12.8 and 16.5 metres. The locations of the sensors were chosen such that the hub height of any wind turbine tested was within one metre of the height of a wind speed sensor.

2) One wind direction sensor mounted at 10.0 metres. This sensor is used to determine the possible existence of wind shading for the various wind turbines and anemometers.

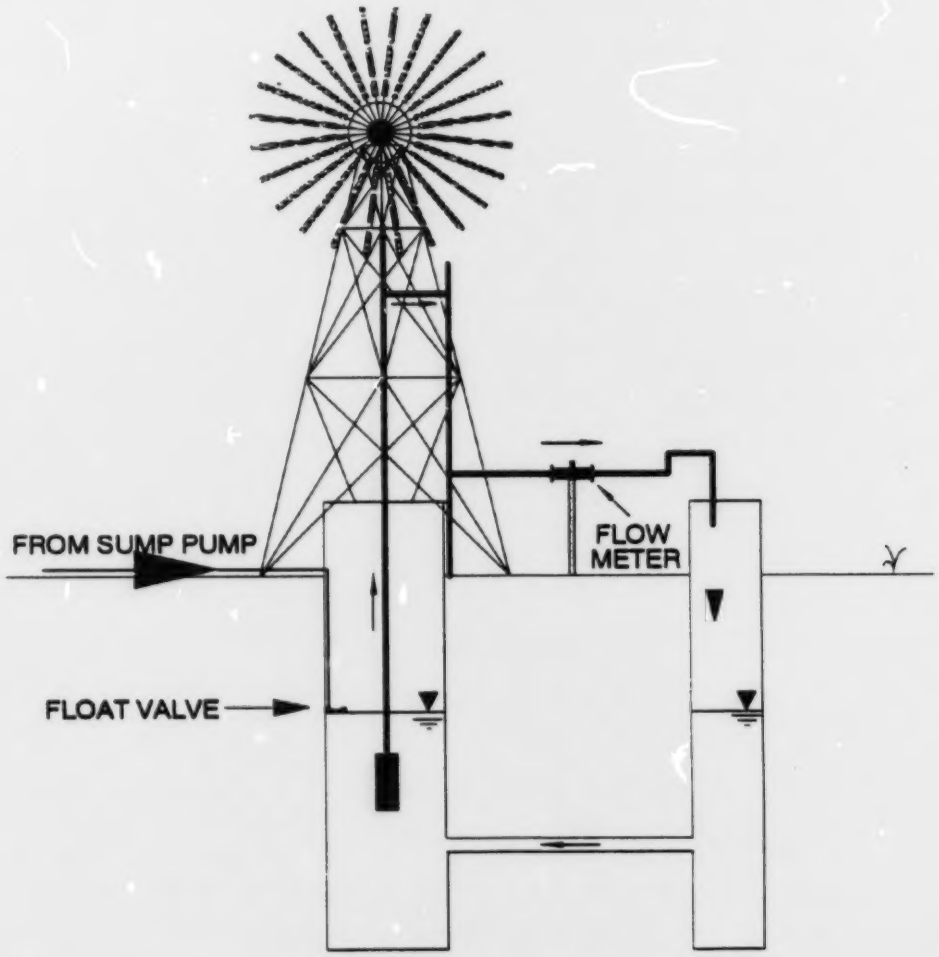


FIGURE 2.2 - TYPICAL PUMPING CIRCUIT

3) One ambient temperature sensor mounted at 10.0 metres and one atmospheric pressure sensor mounted at 2.0 metres. These sensors are used to determine the atmospheric air density.
4) Local displays of the wind speed and direction at the 10.0 metre level for demonstration purposes.
5) Signal conditioners such that all sensor outputs can be transmitted to the data acquisition system in a consistent manner.

The incident solar radiation on the solar pumping systems is monitored by Kipp and Zonen pyranometers. The pyranometers are mounted on the framework of the photovoltaic panels.

There are many parameters which can be measured to evaluate the performance of solar and wind turbine pumping systems. It was decided that the performance variables of most interest to users and manufacturers are: the volume flow rate as a function of wind speed and solar energy; the variation of flow with pumping head and the predicted flow volumes in a given solar and wind regime. Infrared photo pickups are also installed on wind systems to monitor their rotor speed or pump cycle speed. The solar systems have voltage and current sensors to monitor the power which is transferred to the pump from the photovoltaic panels.

The monitoring system on the site consists of a SAFE 8000 data acquisition unit and an IBM PC/XT. The SAFE 8000, programmed in an extended BASIC, samples all atmospheric sensors each second and calculates the one and ten minute average and standard deviation of these values. In addition, the one second peak wind gust at the 12.8 metre level is also determined on the theory that turbine failure will more likely result from instantaneous high wind gusts than from sustained high average winds. The pulse inputs from the flow meters and photo pickups are totalled at the end of each one and ten minute interval coinciding with the atmospheric measurements. At the end of the ten minute interval, the minimum one minute value over the ten minutes is also determined. This value indicates whether the pumping system began or stopped pumping during that ten minute interval. The results of these calculations are then

transmitted to the IBM PC/XT. Both systems are housed in an environmentally controlled trailer located at the south end of the test site. The flow of data through the SAFE 8000 and the IBM PC/XT is illustrated in Figure 2.3. The IBM uses a UNIX based operating system such that it can operate in a multiuser/multitasking environment. A series of scheduled programs, written in C language, is used to facilitate the data collection, processing and transmission. The on-site processing includes producing hourly averages of each sensor input and automatically producing daily summary reports of these values. The ten minute average data is stored on the hard disk (providing thirty days of backup storage), and is regularly retrieved by a remote PC for archiving and analysis. A menu system is provided to on-site and remote users (connected via modem) enabling them to perform a variety of functions. These include manual initiation of the previously discussed automated procedures for any data interval. The user may also obtain, in a similar fashion, data from any of the machines being tested for direct use with a spreadsheet/graphics package such as Lotus 1-2-3. Finally, the menu system allows the user to monitor, in real time, the operation of the site using the one minute data. The operating system is also configured such that password protection prevents unauthorized personnel from modifying the IBM or SAFE software. Because of the UNIX based operating system, all of these tasks can be performed without interrupting the data monitoring process.

3.0 ANALYSIS PROCEDURES

3.1 Reliability

One of the most important factors in evaluating a pumping system is its reliability. Therefore, the test site maintains operating logs of each machine. These logs include their installation date and down times due to machine repair. The logs are used to

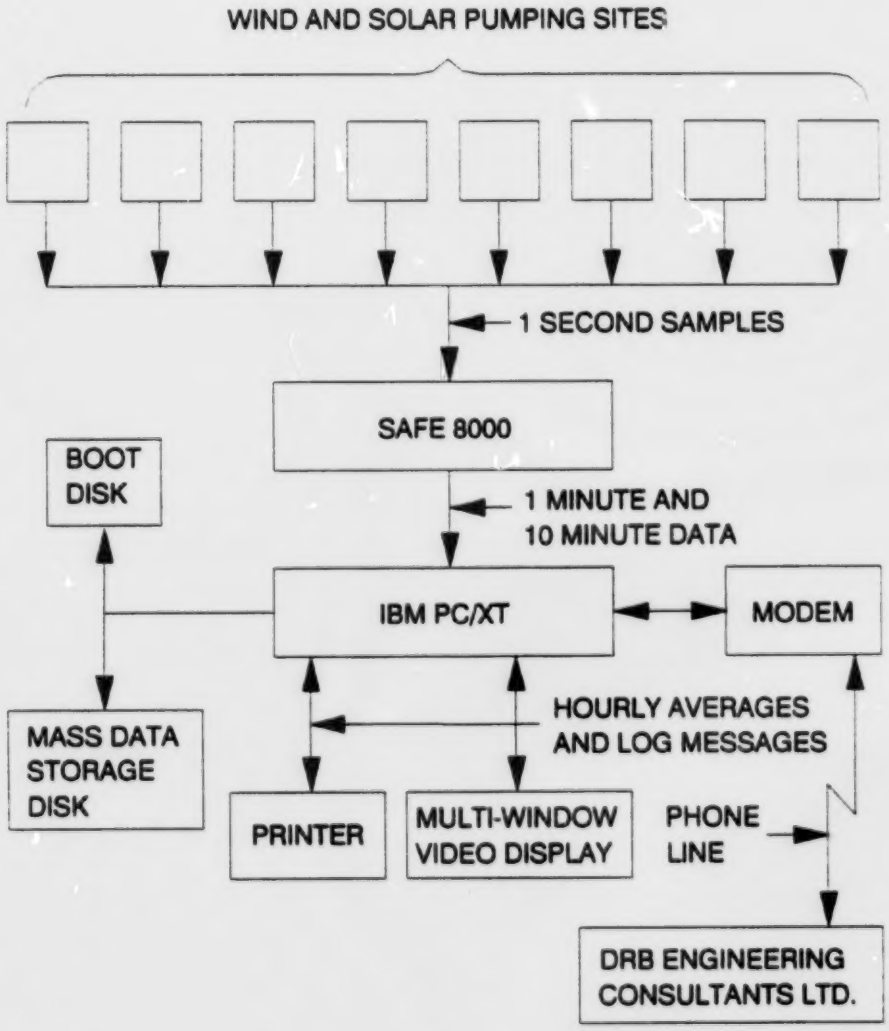


FIGURE 2.3 - DATA ACQUISITION SYSTEM

calculate the number of days the machines were tested and the fraction of time during this test period the machines were available for operation (regardless of wind or cloud conditions). This data is presented with the performance data of each system.

3.2 Wind Performance Curves

The monitoring and analysis procedures at the test site closely follow the Canadian Standards Association (CSA) Standard F417-M91 "Wind Energy Conversion Systems (WECS)-Performance". The monitoring method of sampling once per second and averaging over a ten minute interval agrees with the CSA standard. The only exception to the monitoring standard is that the test site does not have a separate anemometer for each wind turbine being tested. Not only would this have been a costly modification, but because of the smooth terrain characteristics of the site it was deemed unnecessary.

The collected data was first divided into separate files for each machine. These files were then filtered for invalid data sets caused by machine or monitoring failures. The wind turbine files were filtered for data sets in which the anemometers or the machine could have been shaded by surrounding turbines. In the case of the Dutch Delta 16 the data was also filtered for periods when the wind may have been shaded by a section of trees located across the canal and south of the test site. To correctly identify which records required elimination due to wind shading, a study was performed on the wind angle variation which occurs over 10 minute intervals at the test site. The results showed that the median standard deviation was 15 degrees, which meant there was a 5% chance that the wind direction would deviate more than 30 degrees from the mean (2 standard deviations) for a period of one second in the ten minute interval (assuming a normal distribution). The percentage chance would quickly approach zero as the time interval for wind directions outside the 30 degree range was increased. Hence, any data in which the mean wind direction was within 30 degrees

of an obstruction was eliminated. This differs from the CSA standard which requires the mean wind direction to be 45 degrees away from an obstruction.

After the above two filtering methods were applied to the data files, the data sets were divided into wind speed bins. For wind speeds less than 8 m/s, the width of each wind speed bin was 0.5 m/s; for winds greater than 8 m/s, the bin width was 1.0 m/s. This increased interval still agrees with the CSA standard and was applied due to the decreased amount of data recorded above 8 m/s. The mean and standard deviation of each recorded parameter was then calculated for each wind speed bin. The results were then used for the final filtering process. Chauvenet's criterion (Holman, 1978) allows the elimination of spurious data with unknown origins which is greater than approximately two standard deviations away from the mean within each wind speed bin. This criterion was applied as per the CSA standard to the measured flow rates and, if monitored, the rotor speeds. The averages and standard deviations for all parameters in each wind speed bin were then recalculated.

A final test specified by the CSA standard to determine the statistical validity of the data was applied before graphing the results. This final test checks to see if the data meets specified minimum data base requirements (MDBR) and is defined as follows:

1) For wind speed bins in which the parameter to be graphed (flow rate or rotor speed) is less than 25% of the maximum or rated value, then the bin shall not meet the MDBR until at least forty 10 minute averages (samples) are obtained. This controls the data such that the true mean of the bin is contained within a confidence interval of 1 standard deviation of the sample mean with a probability of 0.99.
2) For wind speed bins less than 15 m/s, the bin does not satisfy the MDBR until; (a) there is at least ten samples in the bin, (b) there is a probability of 0.99 that the true mean of the bin is within 10% of the sample mean. The method for determining this value is presented in detail in the CSA standard.

3) For wind speed bins greater than 15 m/s, the bin does not satisfy the MDBR until; (a) there is at least ten samples in the bin, (b) there is a probability of 0.99 that the true mean of the bin is within 20% of the sample mean. This calculation is a slight variation of the above.

The results of the MDBR test, along with the average and standard deviations of each parameter within each bin are tabulated and presented with the performance results. Smooth curves of the data are generated by fitting fifth order polynomial equations to the tabulated values. The coefficients of the resulting equations are then used for subsequent volume yield calculations.

3.3 Monthly Pumping Estimates

The final calculation made from the performance curves is the potential monthly pumping estimates. These estimates are based on the pumping system being available for operation whenever the wind speed exceeds the cut-in speed of the system. They are also based on wind regimes which display Rayleigh characteristics. That is, the frequency of time winds are found within any wind speed interval (e.g. from v_x to v_y) may be calculated by incorporating the mean wind speed ($\bar{v}$) in the following equation:

$$F(v_x \le v \le v_y) = \exp\left[-\left(\frac{\pi}{4}\right)\left(\frac{v_x}{\bar{v}}\right)^2\right] - \exp\left[-\left(\frac{\pi}{4}\right)\left(\frac{v_y}{\bar{v}}\right)^2\right]$$

To calculate the wind turbine's monthly pumping potential, the flow rate values determined by the fifth order polynomial fit to the binned data is integrated with the fraction of time (F) that the wind would blow within each wind speed interval. The sum of these values is equal to the average pumping rate of the wind turbine. The

potential volume the system could pump is then determined by multiplying this average with the time period in question (this study uses 30 day months). Repeating this calculation for a variety of mean wind speeds allows the graphing of the monthly pumping potential against mean wind speed.

3.4 Solar Performance Curves

Performance curves for the solar pumping systems were determined by the same algorithm as the wind pump systems. The only specific changes were:

1) the solar files were filtered for invalid data sets caused by the pyranometers and/or photovoltaic panels being shaded by a nearby utility pole.
2) the performance data was divided into solar radiation intensity bins. For solar radiation values less than 800 W/m^2, the width of each bin was 50 W/m^2; for solar radiation values greater than 800 W/m^2, the width of each bin was 100 W/m^2.
3) no monthly pumping yields were determined because of the lack of a standard method of describing the distribution of solar radiation intensity values.

4.0 PRESENTATION AND DISCUSSION OF RESULTS

The following section presents and discusses the performance characteristics of the pumping systems tested. The machines are discussed in alphabetical order according to the manufacturer's name and are presented as "pull-out" sections. Each "Specification and Performance Summary" page has a corresponding "Method of Bin Results" page. In the case of the wind turbine tables the air density observed in each wind speed bin is reported. In accordance with the CSA performance testing standard, the performance data have not been

adjusted to standard atmospheric conditions. On some of the wind turbine summary tables the turbulence intensity is also indicated. The turbulence intensity is a measure of the variability of the wind speed over each ten minute period and is expressed as the ratio of the first standard deviation of wind speed to the mean wind speed. An analysis for the entire period showed that the average turbulence intensity for winds at ten metres elevation was fourteen percent. This is a relatively low value which provides another indication that the data collected by the meteorological tower accurately represents the winds experienced by the entire site.

The summary tables for the solar pumping systems indicate the average wind speed and ambient air temperature at which the data was recorded. These two parameters will affect the surface temperature that the photovoltaic panels attain during the test. This is important as the performance of the photovoltaic panels are affected by their surface temperature. However, as with the air density effect on wind turbines, no performance correction has been made for the panel temperature effect on the solar systems.

LETHBRIDGE WIND RESEARCH TEST SITE
1991 TEST RESULTS OF
CANADIAN AGTECHNOLOGY PARTNERS SOLAR SYSTEMS

Canadian Agtechnology Partners tested several photovoltaic pumping systems in 1991. This year marked the first year in which the majority of testing was to demonstrate the abilities of their commercial systems. Previously, Canadian Agtechnology Partners (CAP) utilized the test site for the development phase of their systems. The demonstration of their commercial systems in 1991 was also designed to determine the limitations of each system. Thus, not all systems evaluated would find common application in the marketplace.

The CAP systems achieved 100% reliability over the relatively short test season. (The spring portion of testing was committed to short term tests to evaluate configuration possibilities.) All systems were able to begin water pumping at or below an incident solar radiation level of 200 W/m^2. This is significantly better than their original designs which typically required 300 W/m^2 to begin pumping. Likewise, none of their systems peaked prior to maximum solar radiation. This indicates that they have been able to utilize all available power from the solar panels.

Canadian Agtechnology Partners have indicated a desire to continue participation on the test site. They plan to continue you to use the site for system development as well as demonstrate the operation and reliability of some of their commercial systems.

METHOD OF BIN RESULTS FOR: CAP 2-47-T-M2
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO. I	BIN INTERVAL KW/M²	# OF DATA SETS N	BIN SOLAR RAD. KW/M²	SAMPLE AVERAGE FLOW RATE L/M	--SOLAR PANEL OUTPUT--- CURRENT AMPS	VOLTAGE VOLTS	POWER WATTS	STANDARD DEVIATION FLOW RATE L/M	--SOLAR PANEL OUTPUT--- CURRENT AMPS	VOLTAGE VOLTS	POWER WATTS	MEET CSA MDBR REQUIREMENTS FLOW RATE	CUR-RENT	VOLT-AGE	POWER
1	0.00 TO 0.05	-	-	-	-	-	-	-	-	-	-	N	N	N	N
2	0.05 TO 0.10	-	-	-	-	-	-	-	-	-	-	N	N	N	N
3	0.10 TO 0.15	-	-	-	-	-	-	-	-	-	-	N	N	N	N
4	0.15 TO 0.20	-	-	-	-	-	-	-	-	-	-	N	N	N	N
5	0.20 TO 0.25	11	0.232	0.40	1.367	9.20	13.62	0.28	0.126	1.05	2.36	N	Y	N	N
6	0.25 TO 0.30	50	0.280	0.55	1.589	10.74	18.02	0.40	0.157	1.30	3.17	Y	Y	Y	Y
7	0.30 TO 0.35	65	0.326	0.94	1.779	11.82	21.79	0.64	0.188	1.23	3.68	Y	Y	Y	Y
8	0.35 TO 0.40	70	0.374	1.95	1.953	12.43	25.31	0.94	0.222	1.23	4.32	N	Y	Y	Y
9	0.40 TO 0.45	63	0.425	2.54	2.062	12.86	27.54	1.23	0.238	1.19	4.71	N	Y	Y	Y
10	0.45 TO 0.50	85	0.473	3.20	2.180	13.33	30.24	1.62	0.294	1.29	6.01	N	Y	Y	Y
11	0.50 TO 0.55	81	0.528	3.26	2.235	13.44	31.33	1.49	0.287	1.07	5.97	N	Y	Y	Y
12	0.55 TO 0.60	109	0.574	3.99	2.359	13.93	33.68	1.72	0.295	1.03	6.28	N	Y	Y	Y
13	0.60 TO 0.65	116	0.625	4.26	2.428	14.14	35.14	1.67	0.266	0.96	5.90	N	Y	Y	Y
14	0.65 TO 0.70	152	0.676	4.98	2.570	14.56	38.26	1.44	0.255	0.90	5.69	Y	Y	Y	Y
15	0.70 TO 0.75	174	0.726	5.65	2.705	14.98	41.17	1.10	0.214	0.75	4.79	Y	Y	Y	Y
16	0.75 TO 0.80	186	0.774	6.13	2.816	15.35	43.58	0.85	0.179	0.54	4.01	Y	Y	Y	Y
17	0.80 TO 0.85	197	0.826	6.62	2.930	15.67	46.21	0.62	0.149	0.44	3.24	Y	Y	Y	Y
18	0.85 TO 0.90	251	0.877	6.96	3.010	15.93	48.20	0.45	0.115	0.39	2.59	Y	Y	Y	Y
19	0.90 TO 0.95	331	0.928	7.21	3.067	16.09	49.50	0.36	0.112	0.34	2.58	Y	Y	Y	Y
20	0.95 TO 1.00	558	0.979	7.36	3.110	16.18	50.38	0.35	0.126	0.33	2.88	Y	Y	Y	Y
21	1.00 TO 1.10	1039	1.034	7.44	3.118	16.31	50.89	0.35	0.129	0.35	2.97	Y	Y	Y	Y
22	1.10 TO 1.20	37	1.118	7.62	3.156	16.58	52.33	0.28	0.108	0.32	2.60	Y	Y	Y	Y
23	1.20 TO 1.30	-	-	-	-	-	-	-	-	-	-	N	N	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 3575
AVERAGE TEMPERATURE
DURING THE TEST: 294.2 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 4.15 M/S

LETHBRIDGE WIND RESEARCH TEST SITE

SPECIFICATIONS and PERFORMANCE SUMMARY

1991 TEST SEASON

SOLAR PUMP NAME: **CAP 2-47-T-M2**

SUPPLIER: Canadian
Agtechnology Partners

ADDRESS: P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0

TELEPHONE: (403) 556-8779

PHYSICAL DESCRIPTION:

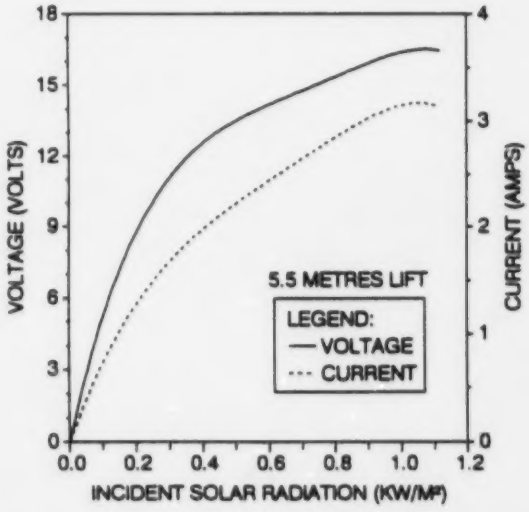
- Number of Panels: 2
- Panel Manufacturer: Siemens
- Power Rating @ 25 C and 1000 W/m²: 47 W/panel
- Configuration: parallel
- Mount: tracking
- Pump Type: floating centrifugal (M2)

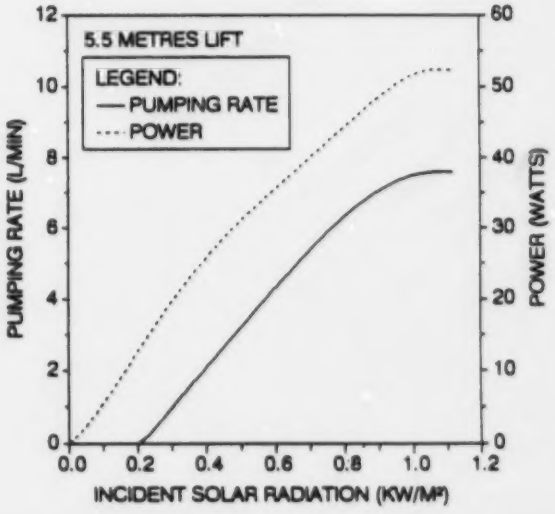
PERFORMANCE:

Testing Period:	77 days
Period Operational:	77 days
Percent Availability:	100 %

INSTALLED: July 5, 1991

1991 PERFORMANCE TEST RESULTS





METHOD OF BIN RESULTS FOR: CAP 3-43-M-F4
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL KW/M²	# OF DATA SETS	BIN SOLAR RAD.	SAMPLE AVERAGE FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	STANDARD DEVIATION FLOW RATE	--SOLAR PANEL OUTPUT--- CURRENT	VOLTAGE	POWER	MEET CSA MOBR REQUIREMENTS FLOW RATE	CUR-RENT	VOLT-AGE	POWER
I		N	KW/M²	L/M	AMPS	VOLTS	WATTS	L/M	AMPS	VOLTS	WATTS				
1	0.00 TO 0.05	-	-	-	-	-	-	-	-	-	-	N	N	N	N
2	0.05 TO 0.10	-	-	-	-	-	-	-	-	-	-	N	N	N	N
3	0.10 TO 0.15	-	-	-	-	-	-	-	-	-	-	N	N	N	N
4	0.15 TO 0.20	4	0.184	0.13	1.643	0.54	1.25	0.06	0.119	0.13	0.48	N	N	N	N
5	0.20 TO 0.25	24	0.233	0.47	2.077	0.94	3.38	0.49	0.119	0.42	2.49	N	Y	N	N
6	0.25 TO 0.30	76	0.276	0.55	2.461	1.21	4.18	0.56	0.154	0.52	2.72	Y	Y	Y	Y
7	0.30 TO 0.35	110	0.326	0.94	2.879	1.83	6.42	0.78	0.154	0.70	3.33	Y	Y	Y	Y
8	0.35 TO 0.40	151	0.376	2.12	3.293	2.98	11.56	1.35	0.198	1.08	5.41	Y	Y	Y	Y
9	0.40 TO 0.45	157	0.425	3.57	3.703	4.32	18.10	1.86	0.175	1.56	7.41	Y	Y	Y	Y
10	0.45 TO 0.50	185	0.476	5.43	4.103	5.91	26.48	2.63	0.215	2.20	10.32	N	Y	Y	Y
11	0.50 TO 0.55	191	0.525	7.61	4.429	7.78	37.29	2.63	0.284	2.11	10.03	Y	Y	Y	Y
12	0.55 TO 0.60	165	0.574	10.05	4.748	9.76	49.14	2.35	0.336	1.89	8.64	Y	Y	Y	Y
13	0.60 TO 0.65	183	0.625	12.21	5.039	11.44	59.88	1.94	0.278	1.53	6.87	Y	Y	Y	Y
14	0.65 TO 0.70	165	0.675	13.22	5.177	12.16	65.12	1.99	0.306	1.55	7.80	Y	Y	Y	Y
15	0.70 TO 0.75	164	0.724	14.15	5.308	12.89	70.13	1.70	0.273	1.32	7.19	Y	Y	Y	Y
16	0.75 TO 0.80	165	0.776	14.78	5.395	13.32	73.37	1.54	0.267	1.15	6.47	Y	Y	Y	Y
17	0.80 TO 0.85	173	0.825	15.00	5.460	13.54	75.48	1.49	0.237	1.07	5.86	Y	Y	Y	Y
18	0.85 TO 0.90	176	0.874	15.32	5.502	13.77	76.88	1.30	0.220	0.85	5.09	Y	Y	Y	Y
19	0.90 TO 0.95	205	0.927	15.68	5.562	14.04	78.72	0.93	0.209	0.55	4.57	Y	Y	Y	Y
20	0.95 TO 1.00	315	0.978	15.88	5.563	14.17	79.11	0.79	0.200	0.45	4.36	Y	Y	Y	Y
21	1.00 TO 1.10	306	1.027	16.21	5.654	14.41	81.66	0.73	0.208	0.40	4.66	Y	Y	Y	Y
22	1.10 TO 1.20	9	1.121	16.39	5.768	14.75	85.23	0.52	0.175	0.50	5.45	N	N	N	N
23	1.20 TO 1.30	-	-	-	-	-	-	-	-	-	-	N	N	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 2924
AVERAGE TEMPERATURE
DURING THE TEST: 292.6 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 4.31 M/S

LETHBRIDGE WIND RESEARCH TEST SITE

SPECIFICATIONS and PERFORMANCE SUMMARY

1991 TEST SEASON

SOLAR PUMP NAME: **CAP 3-43-M-F4**

SUPPLIER: Canadian
Agtechnology Partners

ADDRESS: P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0

TELEPHONE: (403) 556-8779

PHYSICAL DESCRIPTION:

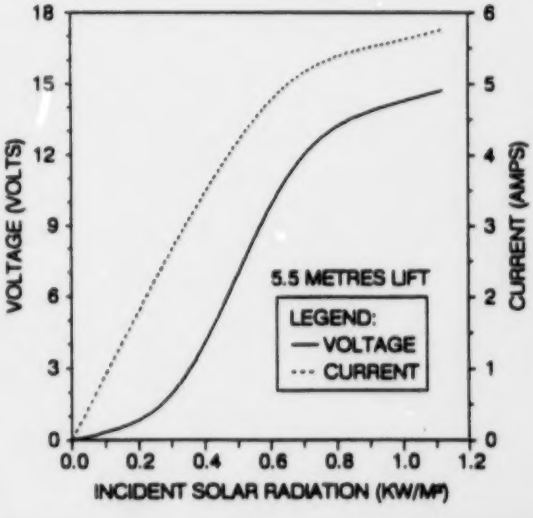
- Number of Panels: 3
- Panel Manufacturer: Siemens
- Power Rating @ 25 C and 1000 W/m²: 43 W/panel
- Configuration: parallel
- Mount: fixed
- Pump Type: 4 valve diaphragm (F4)

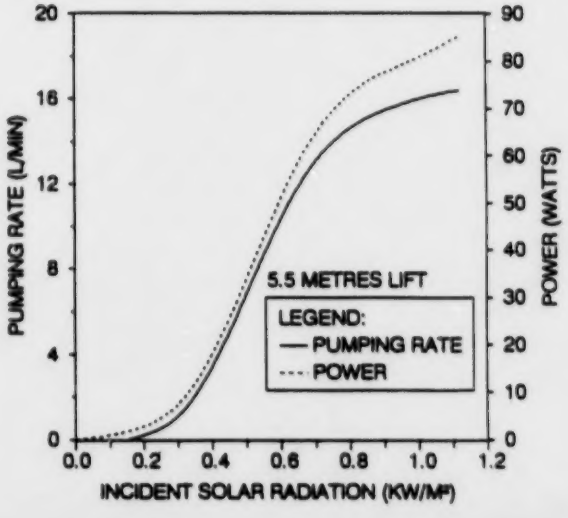
PERFORMANCE:

Testing Period:	106 days
Period Operational:	106 days
Percent Availability:	100 %

INSTALLED: June 5, 1991

1991 PERFORMANCE TEST RESULTS





METHOD OF BIN RESULTS FOR: CAP 4-47-T-RU
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO. I	BIN INTERVAL KW/M²	# OF DATA SETS N	BIN SOLAR RAD. KW/M²	SAMPLE AVERAGE FLOW RATE L/M	--SOLAR PANEL OUTPUT--- CURRENT AMPS	VOLTAGE VOLTS	POWER WATTS	---- STANDARD DEVIATION ----- FLOW RATE L/M	--SOLAR PANEL OUTPUT--- CURRENT AMPS	VOLTAGE VOLTS	POWER WATTS	---- MEET CSA MDBR ---- REQUIREMENTS ---- FLOW RATE	CURRENT	VOLTAGE	POWER
1	0.00 TO 0.05	-	-	-	-	-	-	-	-	-	-	N	N	N	N
2	0.05 TO 0.10	-	-	-	-	-	-	-	-	-	-	N	N	N	N
3	0.10 TO 0.15	-	-	-	-	-	-	-	-	-	-	N	N	N	N
4	0.15 TO 0.20	-	-	-	-	-	-	-	-	-	-	N	N	N	N
5	0.20 TO 0.25	3	0.236	1.02	2.710	4.03	14.27	0.74	0.115	0.39	2.76	N	N	N	N
6	0.25 TO 0.30	14	0.282	0.88	3.239	5.13	19.99	1.01	0.182	0.52	2.58	N	Y	Y	N
7	0.30 TO 0.35	23	0.328	1.47	3.777	5.95	27.74	1.25	0.187	0.61	3.51	N	Y	Y	N
8	0.35 TO 0.40	45	0.377	1.93	4.296	6.68	34.46	1.84	0.214	0.73	4.02	Y	Y	Y	Y
9	0.40 TO 0.45	42	0.427	3.21	4.870	7.57	43.46	2.81	0.195	0.72	5.04	Y	Y	Y	Y
10	0.45 TO 0.50	61	0.474	3.36	5.408	8.38	51.82	3.36	0.236	0.89	5.09	Y	Y	Y	Y
11	0.50 TO 0.55	79	0.530	5.81	6.004	8.97	61.23	4.19	0.236	0.89	4.75	Y	Y	Y	Y
12	0.55 TO 0.60	118	0.576	5.39	6.592	9.90	70.64	4.41	0.263	1.03	5.44	Y	Y	Y	Y
13	0.60 TO 0.65	151	0.626	6.18	7.179	10.74	81.39	5.01	0.301	1.03	5.94	Y	Y	Y	Y
14	0.65 TO 0.70	210	0.676	9.36	7.713	11.23	90.43	4.96	0.319	0.92	5.83	Y	Y	Y	Y
15	0.70 TO 0.75	241	0.726	13.48	8.220	11.58	98.74	4.60	0.334	0.83	5.99	Y	Y	Y	Y
16	0.75 TO 0.80	262	0.774	17.24	8.738	11.96	107.16	3.34	0.309	0.69	5.49	Y	Y	Y	Y
17	0.80 TO 0.85	256	0.826	21.65	9.226	12.27	115.45	3.81	0.322	0.57	5.52	Y	Y	Y	Y
18	0.85 TO 0.90	345	0.877	25.72	9.650	12.49	122.64	3.61	0.305	0.52	5.01	Y	Y	Y	Y
19	0.90 TO 0.95	440	0.927	29.38	10.040	12.78	129.39	2.92	0.299	0.34	4.75	Y	Y	Y	Y
20	0.95 TO 1.00	775	0.978	32.02	10.316	12.94	134.02	2.94	0.320	0.25	5.11	Y	Y	Y	Y
21	1.00 TO 1.10	1262	1.033	35.12	10.596	13.11	139.22	3.08	0.397	0.20	6.44	Y	Y	Y	Y
22	1.10 TO 1.20	44	1.120	39.36	11.043	13.39	148.05	3.13	0.406	0.16	6.64	Y	Y	Y	Y
23	1.20 TO 1.30	-	-	-	-	-	-	-	-	-	-	N	N	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 4371
AVERAGE TEMPERATURE
DURING THE TEST: 293.5 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 4.52 M/S

LETHBRIDGE WIND RESEARCH TEST SITE

SPECIFICATIONS and PERFORMANCE SUMMARY

1991 TEST SEASON

SOLAR PUMP NAME: **CAP 4-47-T-RU**

SUPPLIER: Canadian
Agtechnology Partners

ADDRESS: P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0

TELEPHONE: (403) 556-8779

PHYSICAL DESCRIPTION:

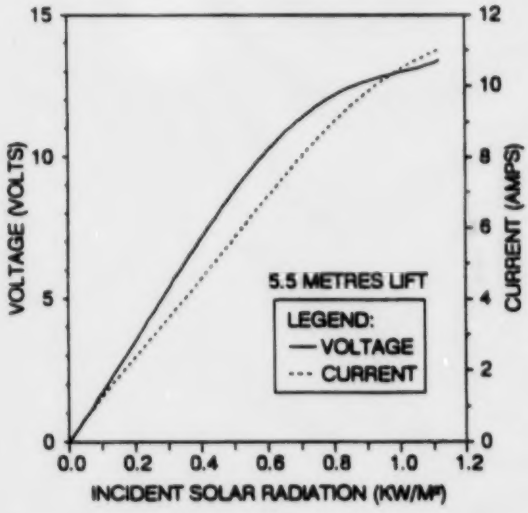
- Number of Panels: 4
- Panel Manufacturer: Siemens
- Power Rating @ 25 C and 1000 W/m²: 47 W/panel
- Configuration: parallel
- Mount: tracking
- Pump Type: floating centrifugal (RU)

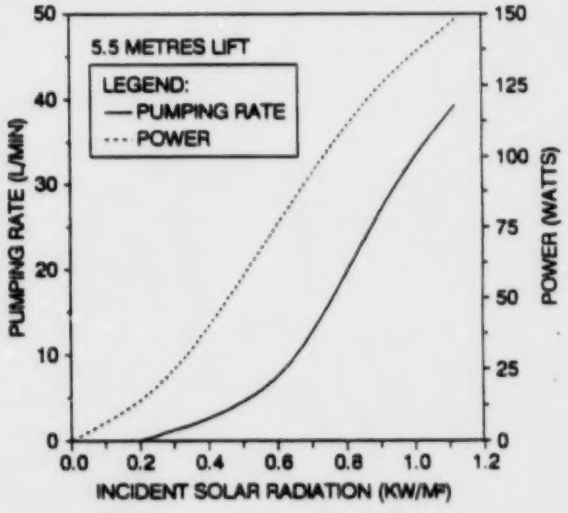
PERFORMANCE:

Testing Period:	106 days
Period Operational:	106 days
Percent Availability:	100 %

INSTALLED: June 5, 1991

1991 PERFORMANCE TEST RESULTS





METHOD OF BIN RESULTS FOR: CAP 8-53-M-RU
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO. I	BIN INTERVAL KW/M²	# OF DATA SETS N	BIN SOLAR RAD. KW/M²	SAMPLE AVERAGE FLOW RATE L/M	--SOLAR PANEL OUTPUT--- CURRENT AMPS	VOLTAGE VOLTS	POWER WATTS	---- STANDARD DEVIATION ----- FLOW RATE L/M	--SOLAR PANEL OUTPUT--- CURRENT AMPS	VOLTAGE VOLTS	POWER WATTS	---- MEET CSA NOBR ---- REQUIREMENTS ---- FLOW RATE	CUR-RENT	VOLT-AGE	POWER
1	0.00 TO 0.05	-	-	-	-	-	-	-	-	-	-	N	N	N	N
2	0.05 TO 0.10	-	-	-	-	-	-	-	-	-	-	N	N	N	N
3	0.10 TO 0.15	-	-	-	-	-	-	-	-	-	-	N	N	N	N
4	0.15 TO 0.20	-	-	-	-	-	-	-	-	-	-	N	N	N	N
5	0.20 TO 0.25	22	0.234	3.03	5.772	9.31	57.90	2.36	0.316	0.69	6.11	N	Y	Y	N
6	0.25 TO 0.30	47	0.278	3.38	6.725	10.82	75.89	2.75	0.428	0.90	8.60	Y	Y	Y	Y
7	0.30 TO 0.35	58	0.327	7.88	7.898	11.82	96.15	5.63	0.407	0.63	7.01	Y	Y	Y	Y
8	0.35 TO 0.40	103	0.377	13.66	8.742	12.36	110.34	7.97	0.690	0.51	11.40	Y	Y	Y	Y
9	0.40 TO 0.45	100	0.425	24.52	9.956	12.90	130.40	8.18	0.667	0.45	11.97	Y	Y	Y	Y
10	0.45 TO 0.50	114	0.476	35.84	11.200	13.43	153.08	6.92	0.643	0.49	11.38	Y	Y	Y	Y
11	0.50 TO 0.55	112	0.524	45.21	12.243	13.90	172.66	6.66	0.636	0.38	11.11	Y	Y	Y	Y
12	0.55 TO 0.60	82	0.573	52.33	13.146	14.30	190.96	5.97	0.666	0.45	11.18	Y	Y	Y	Y
13	0.60 TO 0.65	66	0.624	59.48	14.082	14.81	211.19	4.83	0.592	0.36	10.01	Y	Y	Y	Y
14	0.65 TO 0.70	85	0.676	64.17	14.806	15.18	227.01	4.00	0.481	0.29	8.78	Y	Y	Y	Y
15	0.70 TO 0.75	113	0.724	68.63	15.467	15.51	241.08	3.72	0.491	0.27	9.72	Y	Y	Y	Y
16	0.75 TO 0.80	130	0.776	71.68	15.929	15.74	251.57	3.78	0.547	0.27	11.27	Y	Y	Y	Y
17	0.80 TO 0.85	127	0.825	73.70	16.270	15.90	259.33	3.65	0.564	0.28	12.15	Y	Y	Y	Y
18	0.85 TO 0.90	142	0.873	74.98	16.490	15.99	264.43	3.56	0.587	0.28	12.55	Y	Y	Y	Y
19	0.90 TO 0.95	173	0.925	75.78	16.628	16.07	268.00	3.83	0.637	0.32	13.91	Y	Y	Y	Y
20	0.95 TO 1.00	262	0.978	76.20	16.686	16.09	268.80	3.51	0.596	0.31	13.94	Y	Y	Y	Y
21	1.00 TO 1.10	251	1.027	78.45	17.050	16.26	277.52	3.60	0.652	0.29	14.67	Y	Y	Y	Y
22	1.10 TO 1.20	5	1.119	81.14	17.586	16.47	289.80	2.30	0.439	0.23	11.23	N	N	N	N
23	1.20 TO 1.30	-	-	-	-	-	-	-	-	-	-	N	N	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 1993
AVERAGE TEMPERATURE
DURING THE TEST: 294.1 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 4.11 M/S

LETHBRIDGE WIND RESEARCH TEST SITE

SPECIFICATIONS and PERFORMANCE SUMMARY

1991 TEST SEASON

SOLAR PUMP NAME: **CAP 8-53-M-RU**

SUPPLIER: Canadian
Agtechnology Partners

ADDRESS: P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0

TELEPHONE: (403) 556-8779

PHYSICAL DESCRIPTION:

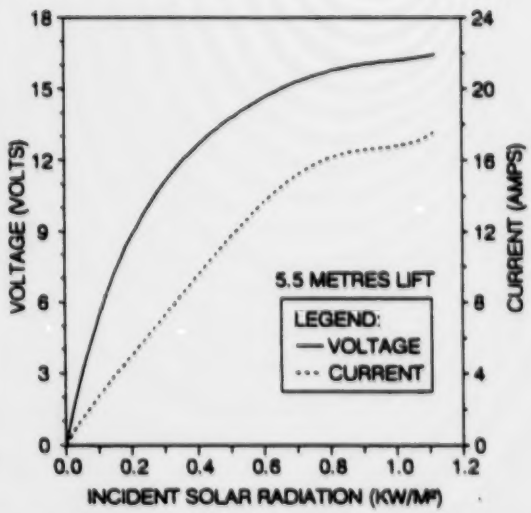
- Number of Panels: 8
- Panel Manufacturer: Siemens
- Power Rating @ 25 C and 1000 W/m²: 53 W/panel
- Configuration: parallel (4) X series (2)
- Mount: fixed
- Pump Type: floating centrifugal (RU)

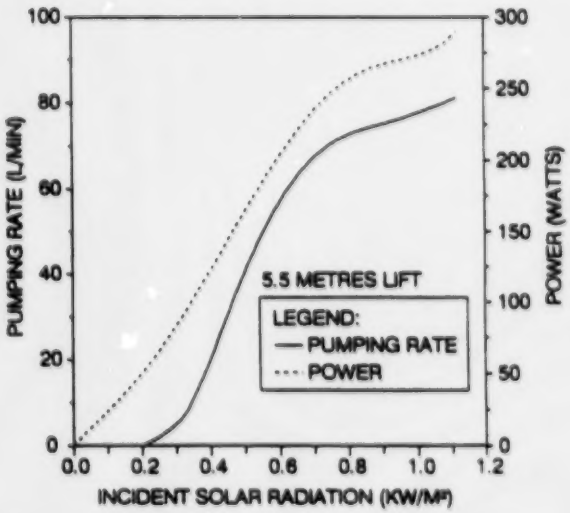
PERFORMANCE:

Testing Period:	63 days
Period Operational:	63 days
Percent Availability:	100 %

INSTALLED: July 18, 1991

1991 PERFORMANCE TEST RESULTS





LETHBRIDGE WIND RESEARCH TEST SITE
1991 TEST RESULTS OF THE
DUTCH DELTA 16

The Dutch wind turbine is a direct drive water pumping wind turbine. The unit has a rotor diameter of 4.9 m and is equipped with what has been termed as a perimeter-bladed rotor. This rotor is a special low-speed version of the delta-wing rotor developed at the University of Calgary. The objective of this design is to achieve maximum torque at cut-in and limit the rotor speed such that it may be directly coupled to a reciprocating pump. To further improve its cut-in wind speed capabilities, the Delta 16 utilizes a counter-balance mechanism. The mechanism requires the turbine to lift a weight equal to half the weight of the water and sucker rod when the pump is on the down stroke. During the pump up stroke, this counter-balance then offsets half the weight of the water and sucker rod. The tower is also unique, as it allows the head, rotor and tail to be assembled near ground level prior to being slid up the inclined tower side. The entire assembly can be slid up one side of the tower by means of a hand winch.

The performance of the Dutch is shown on its specification sheet. These curves show that the wind turbine design has achieved its goal of limiting the rotor speed to under 35 RPM. In a location that has a Rayleigh distribution of winds with a mean of 5 m/s, the Dutch has the potential of pumping 4500 cubic metres per month at 5.5 metres lift. This is 500 cubic metres per month less than the 1990 configuration. The shortfall is the result of a reduced pump size. The smaller pump was for development purposes and would not find common application in the marketplace.

The unit has proven to be highly reliable. It has been operation for 317 of the 338 days of testing performed from 1989 to 1991. During 1991, due to other pump development tests, the final configuration was under test for only 52 days. It was operational for the entire test period. Subsequent to the testing period, this unit was shipped to Texas for demonstrations in the United States. Dutch Industries have also shipped several of the Delta 16's to various developing countries. To simulate pumping conditions for this export market, Dutch Industries now have a slightly modified unit (Delta 16A) under test on one of the deep wells at the Alberta Renewable Energy Test Site. Performance of this machine will be reported in the ARETS 1992 final report.

METHOD OF BIN RESULTS FOR: DUTCH DELTA 16
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--- BIN SAMPLE AVERAGE ---- AIR DENSITY KG/M^3	WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS ROTOR SPEED	FLOW RATE
1	1.5 TO 2.0	-	-	-	-	-	-	-	-	N	N
2	2.0 TO 2.5	13	1.078	2.45	0.6	2.24	0.04	0.2	1.34	N	N
3	2.5 TO 3.0	131	1.083	2.80	1.7	7.82	0.13	1.2	7.06	Y	Y
4	3.0 TO 3.5	287	1.085	3.27	3.0	14.75	0.14	2.1	12.08	Y	Y
5	3.5 TO 4.0	293	1.085	3.74	6.5	34.36	0.14	3.0	18.66	Y	Y
6	4.0 TO 4.5	234	1.084	4.23	11.0	64.40	0.14	2.7	18.22	N	Y
7	4.5 TO 5.0	144	1.074	4.73	14.4	89.45	0.14	2.8	22.60	N	Y
8	5.0 TO 5.5	121	1.076	5.24	18.5	126.05	0.14	2.3	21.35	N	Y
9	5.5 TO 6.0	94	1.071	5.73	21.2	150.50	0.15	2.1	19.22	N	Y
10	6.0 TO 6.5	59	1.072	6.24	25.0	186.55	0.15	2.5	22.89	N	Y
11	6.5 TO 7.0	44	1.068	6.75	26.7	203.37	0.15	2.6	24.18	N	Y
12	7.0 TO 7.5	33	1.066	7.25	28.8	223.97	0.13	2.2	21.97	N	Y
13	7.5 TO 8.0	25	1.059	7.75	31.6	256.96	0.16	2.2	22.58	N	Y
14	8.0 TO 9.0	24	1.066	8.45	31.7	257.20	0.29	2.1	21.67	N	Y
15	9.0 TO 10.0	20	1.062	9.49	28.5	238.95	0.27	3.9	34.40	N	Y
16	10.0 TO 11.0	39	1.063	10.51	16.4	134.98	0.25	6.2	54.65	N	N
17	11.0 TO 12.0	18	1.064	11.39	11.7	91.46	0.27	7.2	62.90	N	N
18	12.0 TO 13.0	3	1.061	12.21	5.4	39.83	0.21	4.0	36.90	N	N
19	13.0 TO 14.0	-	1.072	13.47	3.5	25.55	\			N	N
20	14.0 TO 15.0	-	1.073	14.27	2.7	19.71	| BASED ON 1990 DATA			N	N
21	15.0 TO 16.0	-	1.071	15.67	1.8	13.14	/			N	N
22	16.0 TO 17.0	-	-	-	-	-	-	-	-	N	N
23	17.0 TO 18.0	-	-	-	-	-	-	-	-	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 1582
AVERAGE TEMPERATURE
DURING THE TEST: 294.2 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 91.07 KPA

LETHBRIDGE WIND RESEARCH TEST SITE

SPECIFICATIONS and PERFORMANCE SUMMARY

1991 TEST SEASON

WINDPUMP NAME: **Delta 16**

SUPPLIER: Dutch Industries Ltd.
ADDRESS: 705 - 1st Avenue
Regina, Sask., Canada
S4N 4M4
TELEPHONE: (306) 949-9522

PHYSICAL DESCRIPTION:

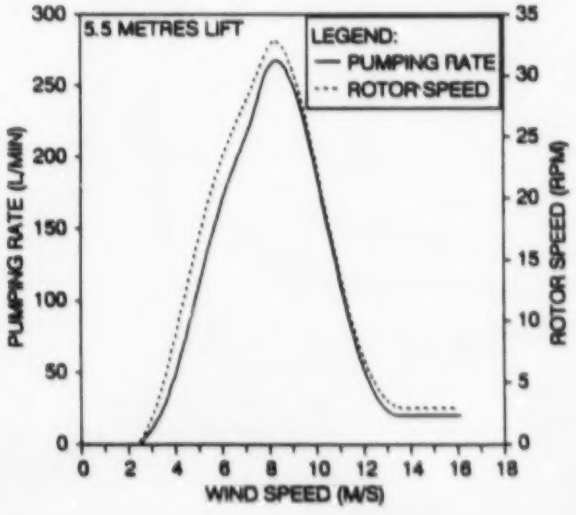
- Turbine Type: upwind
- Axis: horizontal
- Rotor Diameter: 4.82 m
- Swept Area: 7.48 m²
- Number of Blades: 32
- Blade Design: Delta Wing
- Blade Material: mild steel (20 GA)
- Hub Height: 8.25 m
- Transmission: direct drive
- Gear Ratio: 1:1
- Pump Type: reciprocating piston
- Pump Size: 246 mm diameter
- Stroke: 165 mm
- Pumping System Description: reciprocating rod connected to positive displacement pump

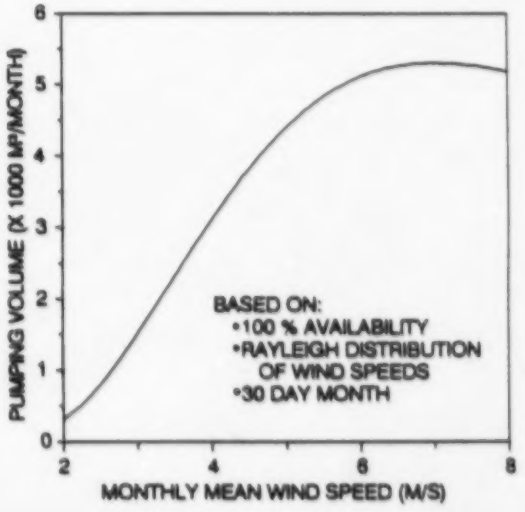
PERFORMANCE:

Testing Period:	52 days
Period Operational:	52 days
Percent Availability:	100 %

INSTALLED: July 29, 1991

1991 PERFORMANCE TEST RESULTS





LETHBRIDGE WIND RESEARCH TEST SITE
1991 TEST RESULTS OF THE
KOENDERS WINDMILL

Koenders Manufacturing Company Ltd. are located in Englefeld, Saskatchewan. This is their first year of testing on the test site. They manufacturer both the windmill and the pump. The pump is designed to both pump water and aerate the water source. The windmill consists of 12 blades mounted on a horizontal shaft. The 1.5 metre diameter rotor is made of galvanized steel. It is directly linked to an 200 mm diameter diaphragm and provides a 19 mm stroke per revolution. The manufacturer reports that 30 psi is developed by this diaphragm. The pressurized air is delivered to a air operated pump. The air entering the pump forces water out of the system and is then released into the surrounding water source. While this occurs, a gasket/float system allows the pump to refill with water by hydraulic pressure. Once filled, the gasket/float system causes the start of the next cycle.

The system tested at Lethbridge had periodic pump problems. The manufacturer suggested that the test sump did not allow sufficient submergence for proper pump operation. These difficulties resulted in 86.7% availability over the 90 day test period. The windmill did not have any failures throughout the test period. Koenders plans to relocate the system to the Alberta Renewable Energy Test Site, where deeper sumps should alleviate the pump problems.

METHOD OF BIN RESULTS FOR: KOENDERS
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO. I	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--BIN SAMPLE AVERAGE-- AIR DENSITY KG/M^3	WIND SPEED M/S	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS FOR FLOW RATE
1	1.5 TO 2.0	120	1.103	1.71	0.20	0.21	0.18	Y
2	2.0 TO 2.5	239	1.083	2.27	0.39	0.14	0.30	Y
3	2.5 TO 3.0	493	1.087	2.77	0.59	0.14	0.45	Y
4	3.0 TO 3.5	571	1.085	3.24	1.02	0.15	0.58	Y
5	3.5 TO 4.0	452	1.083	3.73	1.62	0.14	0.66	Y
6	4.0 TO 4.5	311	1.080	4.23	2.12	0.14	0.65	Y
7	4.5 TO 5.0	213	1.073	4.73	2.60	0.14	0.47	Y
8	5.0 TO 5.5	164	1.075	5.24	3.21	0.14	0.49	Y
9	5.5 TO 6.0	107	1.074	5.72	3.92	0.15	0.44	Y
10	6.0 TO 6.5	72	1.077	6.23	4.34	0.14	0.41	Y
11	6.5 TO 7.0	66	1.073	6.74	4.96	0.14	0.40	Y
12	7.0 TO 7.5	71	1.068	7.23	5.35	0.14	0.36	Y
13	7.5 TO 8.0	58	1.064	7.74	5.82	0.15	0.29	Y
14	8.0 TO 9.0	56	1.071	8.37	6.32	0.27	0.35	Y
15	9.0 TO 10.0	36	1.071	9.39	7.21	0.30	0.33	Y
16	10.0 TO 11.0	25	1.080	10.38	7.80	0.24	0.33	Y
17	11.0 TO 12.0	8	1.079	11.34	8.52	0.30	0.31	N
18	12.0 TO 13.0	-	-	-	-	-	-	N
19	13.0 TO 14.0	-	-	-	-	-	-	N
20	14.0 TO 15.0	-	-	-	-	-	-	N
21	15.0 TO 16.0	-	-	-	-	-	-	N
22	16.0 TO 17.0	-	-	-	-	-	-	N
23	17.0 TO 18.0	-	-	-	-	-	-	N

TOTAL NUMBER OF
REDUCED DATA SETS: 3062
AVERAGE TEMPERATURE
DURING THE TEST: 293.6 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 91.13 KPA

LETHBRIDGE WIND RESEARCH TEST SITE

SPECIFICATIONS and PERFORMANCE SUMMARY

1991 TEST SEASON

WINDPUMP NAME: **Koenders**

SUPPLIER: Koenders Mfg. Co. Ltd.
ADDRESS: P.O. Box 171
Englefield, Saskatchewan, Canada
S0K 1N0
TELEPHONE: (306) 287-3139

PHYSICAL DESCRIPTION:

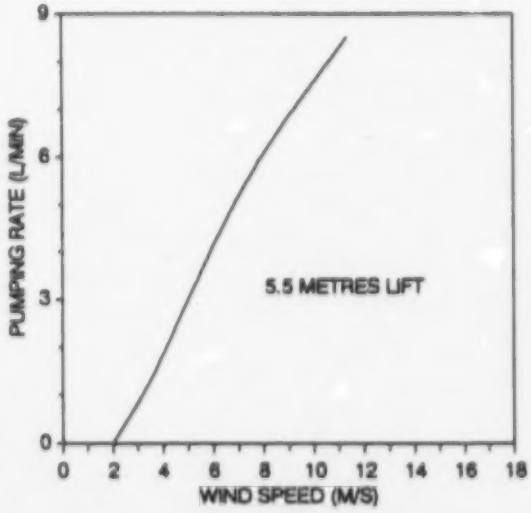
- Turbine Type: upwind
- Axis: horizontal
- Rotor Diameter: 1.57 m
- Swept Area: 1.948 m²
- Number of Blades: 12
- Blade Design: proprietary
- Blade Material: galvanized steel
- Hub Height: 3.66 m
- Transmission: direct drive
- Pump Type: air operated proprietary system
- Pumping System Description:
  windmill driven diaphragm injects air into pump

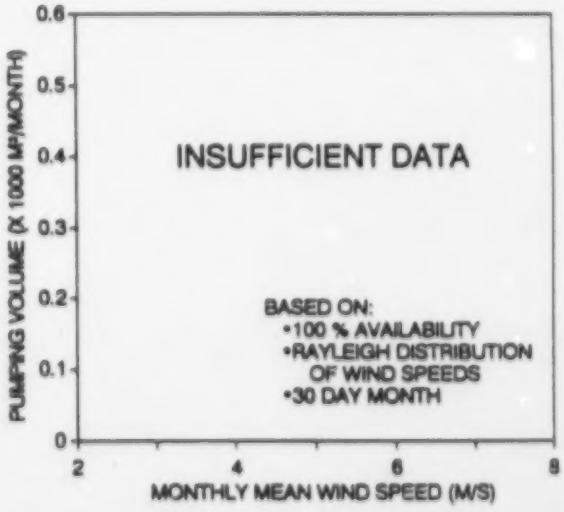
PERFORMANCE:

Testing Period:	90 days
Period Operational:	78 days
Percent Availability:	86.7 %

INSTALLED: June 14, 1991

1991 PERFORMANCE TEST RESULTS





LETHBRIDGE WIND RESEARCH TEST SITE
1991 TEST RESULTS OF THE
MAVERICK WINDMOTOR

The Maverick Windmotor has been tested under several configurations since 1987. The configuration tested in 1991 was very similar to its final configuration in 1990 (it was not tested in 1989). This unit is a downwind, three-bladed machine with a rotor diameter of 2.44 m. It is manufactured in Pincher Creek, Alberta. The rotor is unique because the blades do not radiate out from the central hub, but are mounted perpendicular to the rotor supports at the extreme edge of the rotor circumference. The force of the wind on the blades combined with the rotational speed of the rotor regulates the pitch of the blades. This results in the unit being self regulating and removes the requirement for a cut-out wind speed. The single stage helical progressive cavity pump is driven directly by the rotor via a flexible cable. The pump is designed to produce 13.6 litres per 100 RPM of the rotor.

The performance curves shown on the specification sheet indicates that the system requires a rotor speed of 25 RPM before the pump begins to deliver water. This results in a cut-in wind speed of 2.5 m/s. At 10 m/s the pump delivers 20 litres per 100 RPM of the rotor (40 l/min ÷ 200 rotations/min).

The pump yield curve shows that this turbine can pump 650 cubic metres of water per month at locations with a 5 m/s average monthly wind speed. This is an eight percent improvement over previous years. Using a typical requirement for range cattle of 54 litres per cow per day, this would be sufficient to supply water for 400 cows. This assumes no losses (evaporation, wastage, etc.) and sufficient storage to handle all water pumped.

The manufacturer has begun a major research and development program to continue to improve the rotor and pump designs. The latest modifications to this design are now under test at the Alberta Renewable Energy Test Site.

METHOD OF BIN RESULTS FOR: MAVERICK WINDMOTOR
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--- BIN SAMPLE AVERAGE --- AIR DENSITY KG/M^3	WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS ROTOR SPEED	FLOW RATE
1	1.5 TO 2.0	83	1.088	1.83	6.2	0.00	0.14	4.2	0.02	Y	Y
2	2.0 TO 2.5	292	1.088	2.29	10.0	0.05	0.14	7.4	0.18	Y	Y
3	2.5 TO 3.0	601	1.090	2.77	17.2	0.26	0.14	11.2	0.60	Y	Y
4	3.0 TO 3.5	737	1.087	3.25	26.5	1.16	0.15	13.4	1.48	Y	Y
5	3.5 TO 4.0	652	1.087	3.72	43.7	3.52	0.14	15.2	2.57	Y	Y
6	4.0 TO 4.5	528	1.082	4.23	64.8	7.65	0.14	12.6	2.90	Y	Y
7	4.5 TO 5.0	364	1.075	4.73	82.4	11.53	0.14	11.2	2.83	Y	Y
8	5.0 TO 5.5	326	1.077	5.23	100.0	15.63	0.14	9.4	2.51	Y	Y
9	5.5 TO 6.0	245	1.073	5.72	114.8	19.32	0.14	8.1	2.27	Y	Y
10	6.0 TO 6.5	167	1.072	6.26	130.5	23.12	0.14	8.2	2.31	Y	Y
11	6.5 TO 7.0	172	1.070	6.74	141.4	25.72	0.15	7.8	2.13	Y	Y
12	7.0 TO 7.5	146	1.065	7.24	154.2	28.84	0.15	7.9	2.07	Y	Y
13	7.5 TO 8.0	114	1.065	7.74	165.7	31.50	0.14	7.9	2.17	Y	Y
14	8.0 TO 9.0	123	1.071	8.39	180.0	34.89	0.29	9.7	2.59	Y	Y
15	9.0 TO 10.0	86	1.076	9.45	199.1	39.13	0.31	10.0	2.56	Y	Y
16	10.0 TO 11.0	82	1.074	10.41	215.3	42.70	0.27	8.0	1.94	Y	Y
17	11.0 TO 12.0	22	1.070	11.37	228.4	45.65	0.27	8.2	1.61	Y	Y
18	12.0 TO 13.0	-	1.073	12.53	245.0	49.50	-	-	-	N	N
19	13.0 TO 14.0	-	1.072	13.54	253.8	51.42	BASED ON		-	N	N
20	14.0 TO 15.0	-	1.072	14.52	261.8	53.98	1990 DATA		-	N	N
21	15.0 TO 16.0	-	1.071	15.39	277.5	56.83	-	-	-	N	N
22	16.0 TO 17.0	-	-	-	-	-	-	-	-	N	N
23	17.0 TO 18.0	-	-	-	-	-	-	-	-	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 4741
AVERAGE TEMPERATURE
DURING THE TEST: 293.3 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 90.99 KPA

LETHBRIDGE WIND RESEARCH TEST SITE

SPECIFICATIONS and PERFORMANCE SUMMARY

1991 TEST SEASON

WINDPUMP NAME: **Maverick Windmotor**

SUPPLIER: Maverick Wind Energy Ltd.
ADDRESS: P.O. Box 2707
Pincher Creek, Alberta, Canada
T0K 1W0
TELEPHONE: (403) 627-3630
(403) 627-3091

PHYSICAL DESCRIPTION:

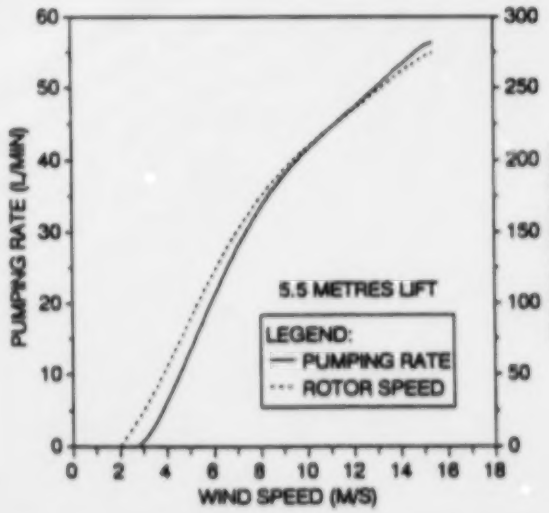
- Turbine Type: downwind
- Axis: horizontal
- Rotor Diameter: 2.44 m
- Swept Area: 4.68 m²
- Number of Blades: 3
- Blade Design: proprietary
- Blade Material: extruded aluminum
- Hub Height: 7.62 m
- Transmission: direct drive
- Gear Ratio: 1 : 1
- Pump Type: helical progressing cavity
- Pump Size: 51 mm diameter
- Pumping System Description: direct cable drive from rotor to pump

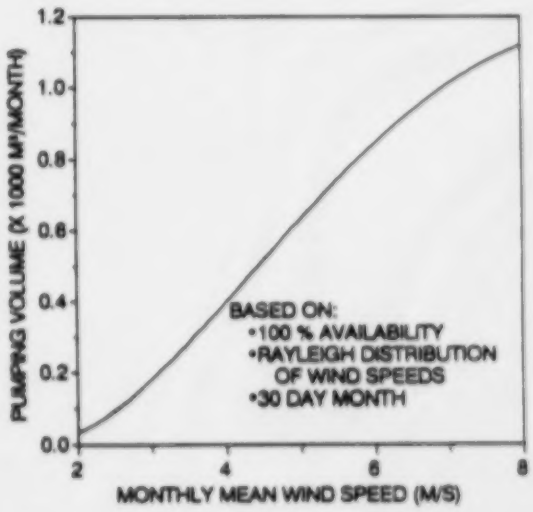
PERFORMANCE:

Testing Period:	92 days
Period Operational:	90 days
Percent Availability:	97.8 %

INSTALLED: June 19, 1991

1991 PERFORMANCE TEST RESULTS





LETHBRIDGE WIND RESEARCH TEST SITE
1991 TEST RESULTS OF THE
NESL SOLARFLO

This is the second photovoltaic pumping system to be tested by Nor'wester Energy Systems Ltd. The performance of the first system (the Solar Econo-sub) is reported in the test sites 1990 final report. Previously, NESL has used the test site to develop an electric wind turbine water pumping system known as the Maestro. Testing of the photovoltaic system acts as the second step towards assembling a hybrid (wind/photovoltaic) system for test.

The Solarflo utilizes two Kyocera 50 Watt panels wired in parallel. The panels are mounted on a non-tracking structure. The output of the panels drive a two valve diaphragm pump. The system distinguishes itself by having the lowest cut-in value (50 Watts/m^2) of all photovoltaic systems tested at the LWRTS. Because of this low cut-in value, this system would not benefit from utilizing a tracking mount. It achieves it peak output at 900 Watts/m^2 of 10.5 l/min. This is substantially greater than the 6 l/min output achieved with the Solar Econo-sub. The system was not installed until July 22 of 1991, allowing for only 60 days of testing. This is not sufficient time to assess the reliability of this system.

Nor'Wester Energy Systems plans to continue development and testing of photovoltaic pumping systems at the Alberta Renewable Energy Test Site in 1992.

METHOD OF BIN RESULTS FOR: NESL SOLARFLO
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO. I	BIN INTERVAL KW/M²	NUMBER OF REDUCED DATA SETS N	BIN SAMPLE AVERAGE SOLAR RAD. KW/M²	FLOW RATE L/MIN	STANDARD DEVIATION SOLAR RAD. KW/M²	FLOW RATE L/MIN	MEET CSA MDBR REQUIREMENTS FOR FLOW RATE
1	0.00 TO 0.05	28	0.044	0.14	0.003	0.11	N
2	0.05 TO 0.10	199	0.073	0.94	0.015	0.42	Y
3	0.10 TO 0.15	154	0.124	1.88	0.015	0.44	Y
4	0.15 TO 0.20	132	0.175	2.78	0.014	0.41	Y
5	0.20 TO 0.25	133	0.225	3.63	0.015	0.45	Y
6	0.25 TO 0.30	101	0.274	4.38	0.015	0.34	Y
7	0.30 TO 0.35	65	0.326	5.14	0.014	0.37	Y
8	0.35 TO 0.40	71	0.377	5.83	0.014	0.39	Y
9	0.40 TO 0.45	73	0.426	6.47	0.015	0.37	Y
10	0.45 TO 0.50	60	0.475	7.01	0.015	0.46	Y
11	0.50 TO 0.55	57	0.523	7.79	0.015	0.60	Y
12	0.55 TO 0.60	46	0.577	8.82	0.014	0.58	Y
13	0.60 TO 0.65	60	0.627	9.73	0.015	0.52	Y
14	0.65 TO 0.70	70	0.676	10.12	0.014	0.47	Y
15	0.70 TO 0.75	65	0.724	10.50	0.015	0.34	Y
16	0.75 TO 0.80	77	0.775	10.65	0.014	0.39	Y
17	0.80 TO 0.85	78	0.826	10.80	0.014	0.38	Y
18	0.85 TO 0.90	88	0.873	10.79	0.014	0.38	Y
19	0.90 TO 0.95	111	0.926	10.87	0.014	0.39	Y
20	0.95 TO 1.00	163	0.978	10.87	0.014	0.38	Y
21	1.00 TO 1.10	166	1.028	10.88	0.022	0.42	Y
22	1.10 TO 1.20	5	1.121	10.76	0.012	0.38	N
23	1.20 TO 1.30	-	-	-	-	-	-

TOTAL NUMBER OF
REDUCED DATA SETS: 2002
AVERAGE TEMPERATURE
DURING THE TEST: 295.5 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 4.10 M/S

LETHBRIDGE WIND RESEARCH TEST SITE

SPECIFICATIONS and PERFORMANCE SUMMARY

1991 TEST SEASON

SOLAR PUMP NAME: **NESL SOLARFLO**

SUPPLIER: Nor'Wester Energy Systems Ltd.

ADDRESS: Box 7, Site 32, R.R. 7
Calgary, Alberta, Canada
T3E 6W3

TELEPHONE: (403) 249-3337

PHYSICAL DESCRIPTION:

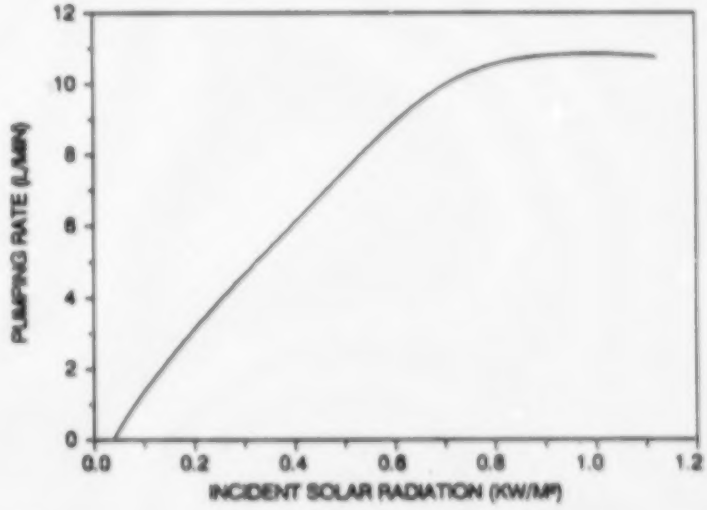
- Number of Panels: 2
- Panel Manufacturer: Kyocera
- Power Rating @ 25 C and 1000 W/m²: 50 W/panel
- Configuration: parallel
- Mount: fixed
- Pump Type: diaphragm (SolarFlo)

PERFORMANCE:

Testing Period:	60 days
Period Operational:	60 days
Percent Availability:	100 %

INSTALLED: July 22, 1991

1991 PERFORMANCE TEST RESULTS



LETHBRIDGE WIND RESEARCH TEST SITE
1991 TEST RESULTS OF THE
PRAIRIE #PD8-6

The Prairie #PD8-6 represents the result of eight years of development by Prairie Ditching of Lethbridge, Alberta. Previous to this entirely custom designed unit, the manufacturer had tested stock and modified versions of the Bowjon Rancher. The results of the Bowjon tests can be found in the summary reports produced by the Lethbridge Wind Research Test Site since 1983. The Prairie rotor consists of 6 polyethylene blades which directly drive an air compressor. The air compressor supplies compressed air which is injected into an air lift pump. The air lift pump consists of a perforated foot piece set in the center of an open-ended cylinder. The air is discharged through the foot piece, thus producing an air and water mixture. The mixture rises because it possesses a lower density than the water surrounding the pump. The advantage of an air lift pump is that it will not be harmed if it experiences dry well or freezing conditions.

The performance of the Prairie unit in 1991 is shown on its specification sheet. The data presented is based on only 16 days of testing. At the time of failure, the manufacturer chose not to repair the system. Thus, the 100% reliability may be misleading. In the Prior two years of testing it was operational 96.5% of the time. During the 16 day test, the unit achieved a peak of 12 l/min, this is substantially lower than the 20 l/min peak found in 1990.

Prairie ditching has not indicated that he will continue his involvement in the wind industry or the test site program.

METHOD OF BIN RESULTS FOR: PRAIRIE WPDS-6
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL M/S	NUMBER OF REDUCED DATA SETS N	--BIN SAMPLE AVERAGE-- AIR DENSITY KG/M^3	WIND SPEED M/S	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	FLOW RATE L/MIN	MEET CSA MOBR REQUIREMENTS FOR FLOW RATE
1	1.5 TO 2.0	12	1.077	1.77	0.32	0.16	0.27	N
2	2.0 TO 2.5	80	1.074	2.30	0.51	0.15	0.50	Y
3	2.5 TO 3.0	250	1.084	2.76	0.82	0.14	0.71	Y
4	3.0 TO 3.5	283	1.080	3.22	2.33	0.14	1.17	Y
5	3.5 TO 4.0	179	1.080	3.72	4.81	0.14	1.19	Y
6	4.0 TO 4.5	109	1.074	4.22	6.72	0.15	1.07	Y
7	4.5 TO 5.0	89	1.067	4.73	8.19	0.15	0.98	Y
8	5.0 TO 5.5	78	1.068	5.24	9.60	0.15	0.77	Y
9	5.5 TO 6.0	59	1.066	5.76	10.51	0.14	0.94	Y
10	6.0 TO 6.5	54	1.072	6.26	11.39	0.14	0.82	Y
11	6.5 TO 7.0	54	1.070	6.75	11.95	0.14	0.87	Y
12	7.0 TO 7.5	61	1.067	7.24	11.74	0.15	0.97	Y
13	7.5 TO 8.0	48	1.061	7.72	11.69	0.15	0.97	Y
14	8.0 TO 9.0	36	1.062	8.32	11.71	0.23	1.21	Y
15	9.0 TO 10.0	15	1.057	9.28	10.98	0.24	1.19	Y
16	10.0 TO 11.0	4	1.067	10.20	10.07	0.11	0.37	N
17	11.0 TO 12.0	-	-	-	-	-	-	N
18	12.0 TO 13.0	-	-	-	-	-	-	N
19	13.0 TO 14.0	-	-	-	-	-	-	N
20	14.0 TO 15.0	-	-	-	-	-	-	N
21	15.0 TO 16.0	-	-	-	-	-	-	N
22	16.0 TO 17.0	-	-	-	-	-	-	N
23	17.0 TO 18.0	-	-	-	-	-	-	N

TOTAL NUMBER OF
REDUCED DATA SETS: 1411
AVERAGE TEMPERATURE
DURING THE TEST: 295.5 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 91.17 KPA

LETHBRIDGE WIND RESEARCH TEST SITE

SPECIFICATIONS and PERFORMANCE SUMMARY

1991 TEST SEASON

WINDPUMP NAME: **Prairie #PD8-6**

SUPPLIER: Prairie Ditching Ltd.
ADDRESS: 418 - 26 Street, South
Lethbridge, Alberta, Canada
T1J 3R2
TELEPHONE: (403) 327-8280

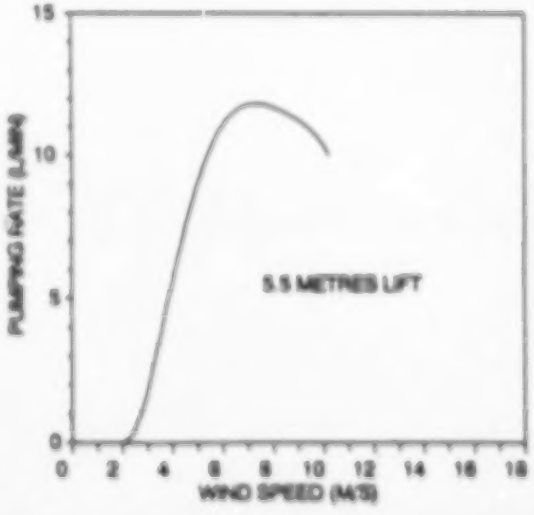
PHYSICAL DESCRIPTION:
- Turbine Type: upwind
- Axis: horizontal
- Rotor Diameter: 2.24 m
- Swept Area: 3.924 m²
- Number of Blades: 6
- Blade Design: proprietary
- Blade Material: polyethelene
- Hub Height: 7.74 m
- Transmission: direct drive
- Pump Type: air lift
- Pumping System Description: windmill driven air compressor

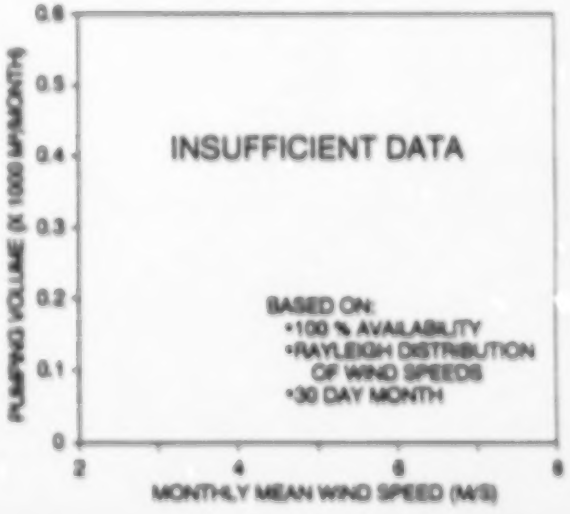
PERFORMANCE:

Testing Period:	16 days
Period Operational:	16 days
Percent Availability:	100 %

INSTALLED: July 24, 1991

1991 PERFORMANCE TEST RESULTS





LETHBRIDGE WIND RESEARCH TEST SITE
1991 TEST RESULTS OF THE
WIND BARON SOFTWIND 21

The Wind Baron is very similar in looks to the standard American water pumper. Its rotor is 6.4 metres in diameter and consists of 18 blades. It utilizes a large (305 mm diameter X 518 mm stroke) positive displacement pump. The torque required to initiate operation of the windmill has been reduced substantially by the use of a counter-balance mechanism. The mechanism requires the turbine to lift a weight (equal to half the weight of the water and all the weight of the sucker rod and pump) when the pump is on the down stroke. During the pump up stroke, this counter-balance then offsets half the weight of the water and all the weight of the sucker rod and pump. Further reductions to start-up torque are achieved by a mechanical gear box which requires 3.25 rotor rotations per pump stroke.

The windmill was installed in 1990 and had some structural modifications made to it in the spring of 1991. It performed very reliably in 1991, achieving 97.6% availability over a 126 day test period.

The data collected shows the machine has an excellent cut-in wind speed of 1.75 m/s. This is in exact agreement with that published by the manufacturer. It is capable of pumping 500 l/min at 13 m/s, suitable for many small scale irrigation applications. It is one of the largest windmills tested at the Lethbridge Wind Research Test Site.

The manufacturer plans to continue development and testing of his mill at the Alberta Renewable Energy Test Site in 1992.

METHOD OF BIN RESULTS FOR: SOFTWIND 21
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL	NUMBER OF REDUCED DATA SETS	--- BIN SAMPLE AVERAGE --- AIR DENSITY	WIND SPEED	ROTOR SPEED	FLOW RATE	STANDARD DEVIATION WIND SPEED	ROTOR SPEED	FLOW RATE	MEET CSA MDBR REQUIREMENTS ROTOR SPEED	FLOW RATE
I	M/S	N	KG/M^3	M/S	RPM	L/MIN	M/S	RPM	L/MIN		
1	1.5 TO 2.0	414	1.092	1.79	1.8	6.03	0.16	0.9	6.66	Y	Y
2	2.0 TO 2.5	1141	1.098	2.26	3.6	17.55	0.14	1.8	12.33	Y	Y
3	2.5 TO 3.0	1349	1.100	2.75	7.3	43.61	0.14	2.2	16.83	Y	Y
4	3.0 TO 3.5	1226	1.098	3.23	11.0	73.65	0.14	2.0	16.27	Y	Y
5	3.5 TO 4.0	1026	1.097	3.74	14.4	103.11	0.15	1.8	16.59	N	Y
6	4.0 TO 4.5	774	1.095	4.24	17.7	134.60	0.14	1.8	17.50	N	Y
7	4.5 TO 5.0	564	1.091	4.73	20.7	163.03	0.15	1.9	18.52	N	Y
8	5.0 TO 5.5	415	1.089	5.24	23.7	192.85	0.15	2.0	19.46	N	Y
9	5.5 TO 6.0	360	1.087	5.73	26.4	221.26	0.15	1.9	21.18	N	Y
10	6.0 TO 6.5	297	1.087	6.22	29.4	252.28	0.14	2.0	22.55	N	Y
11	6.5 TO 7.0	272	1.089	6.73	32.0	278.50	0.14	2.0	22.63	N	Y
12	7.0 TO 7.5	239	1.088	7.24	34.4	305.69	0.14	2.0	24.62	N	Y
13	7.5 TO 8.0	255	1.085	7.73	36.6	333.51	0.14	2.0	24.59	N	Y
14	8.0 TO 9.0	386	1.087	8.46	40.0	374.52	0.29	2.1	28.34	N	Y
15	9.0 TO 10.0	254	1.089	9.50	43.6	419.51	0.28	1.8	26.11	N	Y
16	10.0 TO 11.0	213	1.088	10.51	46.5	464.15	0.29	1.8	29.86	N	Y
17	11.0 TO 12.0	125	1.084	11.41	48.2	490.71	0.27	1.5	26.47	N	Y
18	12.0 TO 13.0	46	1.085	12.39	49.0	503.39	0.26	1.4	21.62	N	Y
19	13.0 TO 14.0	15	1.090	13.37	48.1	498.79	0.22	1.8	22.00	N	Y
20	14.0 TO 15.0	-	-	-	-	-	-	-	-	N	N
21	15.0 TO 16.0	-	-	-	-	-	-	-	-	N	N
22	16.0 TO 17.0	-	-	-	-	-	-	-	-	N	N
23	17.0 TO 18.0	-	-	-	-	-	-	-	-	N	N

TOTAL NUMBER OF
REDUCED DATA SETS: 9372
AVERAGE TEMPERATURE
DURING THE TEST: 289.7 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 90.94 KPA

LETHBRIDGE WIND RESEARCH TEST SITE

SPECIFICATIONS and PERFORMANCE SUMMARY

1991 TEST SEASON

WINDPUMP NAME: **Softwind 21**

SUPPLIER: Wind Baron Corp.
ADDRESS: 3920 East Huntington Drive
Flagstaff, Arizona, U.S.A.
86004
TELEPHONE: (602) 526-6400

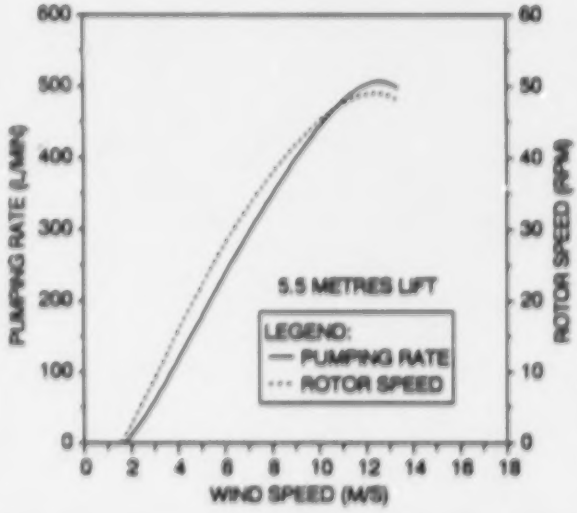
PHYSICAL DESCRIPTION:
- Turbine Type: upwind
- Axis: horizontal
- Rotor Diameter: 6.4 m
- Swept Area: 32.17 m²
- Number of Blades: 18
- Blade Design: high torque sails
- Blade Material: galvinized steel
- Hub Height: 12.2 m
- Transmission: mechanical gearing
- Gear Ratio: 3.25:1
- Pump Type: reciprocating piston
- Pump Size: 305 mm diameter
- Stroke: 518 mm
- Pumping System Description: reciprocating rod connected to positive displacement pump

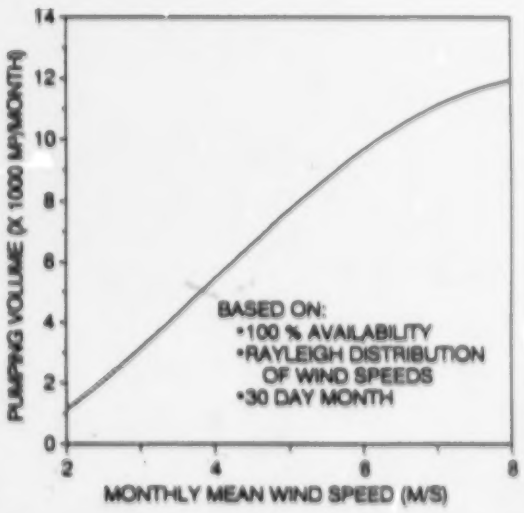
PERFORMANCE:

Testing Period:	126 days
Period Operational:	123 days
Percent Availability:	97.6 %

INSTALLED: May 16, 1991

1991 PERFORMANCE TEST RESULTS





5.0 ALBERTA RENEWABLE ENERGY TEST SITE

5.1 Background

During the 1991 test season, the staff of the Lethbridge Wind Research Test Site designed and constructed a new test site in Pincher Creek, Alberta. The site, known as the Alberta Renewable Energy Test Site is located approximately 60 miles west of Lethbridge and just east of Pincher Creek. A number of factors attributed to the sites relocation. The most significant of these was an Alberta program designed to develop the renewable energy industry within the Pincher Creek area. The program, known as the Southwest Alberta Renewable Energy Initiative (SWAREI), provides financial assistance for commercial renewable energy projects installed within specific geographic boundaries. Coincidentally, this program was created at the time the Alberta/Canada Energy Resources Research Fund (A/CERRF) was depleted. Thus, in recognition of the Test Site's importance to the industry, SWAREI funded the sites relocation and construction at Pincher Creek and agreed to provide the replacement funding required due to A/CERRF's absence.

5.2 Construction

The construction of the test site was almost identical to the Lethbridge site. Four below ground, closed loop pumping circuits were installed to perform the low lift testing in a manner similar to that at LWRTS. The loop differed in that the secondary sump was replaced by a 0.3 metre diameter plastic return line. The primary sump was constructed of concrete culvert sections, place end to end to a depth of 5 metres. The base consisted of a traditional culvert concrete cap. The use of concrete and the elimination of the secondary pump was cost effective and is expected to eliminate leakage problems that were found with the metal sumps at the LWRTS. These four traditional sumps were space in intervals of 30 metres away from the data acquisition trailer. Cantered between every two sumps is an anemometer tower which possesses two wind speed/direction sensors. This results in ARETS meeting the CSA performance testing standard for anemometer distance from the system under test. The

photovoltaic test stands (Site 10 at LWRTS) were relocated to an identical test bed at ARETS.

Two additional test sites were constructed at ARETS to further facilitate testing for export markets. These test sites have as their primary sump a closed 61 metre, 0.152 metre diameter well. The water level within these wells will be controlled by the data acquisition system such that actual high lift conditions can be produced. This is advantageous over the site's Deep Well Simulator in that down hole pumping equipment (eg. sucker rods, hose connections) can be properly tested. (For electric systems, the lack of down hole connections reduces this advantage). In addition, by combining the Deep Well Simulator with one of these wells, tests at 260 metres of lift are obtainable.

5.3 Remote Monitoring Equipment

The Alberta Renewable Energy Test Site has been funded (by Energy, Mines & Resources Canada) to obtain and coordinate the use of five remote monitoring systems. This will enable the test site to continue its periodic remote monitoring services (Paterson et al, 1990) as well as provide other industry proponents with short-term resource monitoring equipment. The equipment will be capable of 30 days of unattended monitoring at CSA standard sampling and averaging intervals. The data will be stored on non-volatile EEPROM such that if any power problems emerge, the data collected will not be lost. This method of storage will also allow cold temperature operation previously not possible with tape storage data loggers. Immediate plans for 1992 include:

1) monitoring the wind resource at the Azorian Islands (near Portugal) by the Abbey Hill Cattle Company.
2) monitoring the wind resource in southern Ontario by the Avalon Group.
3) monitoring a wind pumping system developed by Maverick Wind Energy Ltd. at their design office.
4) monitoring the wind resource at Wrentham, Alberta by Alberta Agriculture.

Additional commitments are expected to arise as the availability of these systems becomes known.

6.0 EVALUATION REPORT

The Alberta Farm Machinery Research Centre has undertaken the production of an Evaluation Report which will contain the performance summaries of systems tested at LWRTS from 1988 to 1991, inclusive. This report is distributed to over 8000 subscribers who are typically responsible for either the purchase or recommendation for purchase of agricultural equipment. The distribution of this report should have an immediate impact on the industry and on the utilization of the test site.

7.0 CONCLUSIONS

The LWRTS evaluated ten pumping systems 1991. All windmill test sites were filled, although one was under construction throughout 1991. Most of the tests performed this year were to demonstrate the abilities of commercial systems. As a result, many of the systems will be relocated to ARETS for continued testing and demonstration.

The interest in the test site by manufacturers has continued to grow. They realize that field testing by an unbiased group provides a number of advantages. First, the data provided allows the manufacturer to further the development of their machines. Second, the reliability testing provides an indication whether the design is ready to be taken to the marketplace. Finally, the field testing at a public test site provides a good marketing tool by demonstrating their machines to large numbers of potential buyers.

Interest from Developing Countries continues to grow. In 1992, a contingent from Niger is planning on touring the site near the beginning of June. It is expected that this group will become local distributors in Niger for one or more of the manufacturers presently on the test site.

8.0 REFERENCES

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